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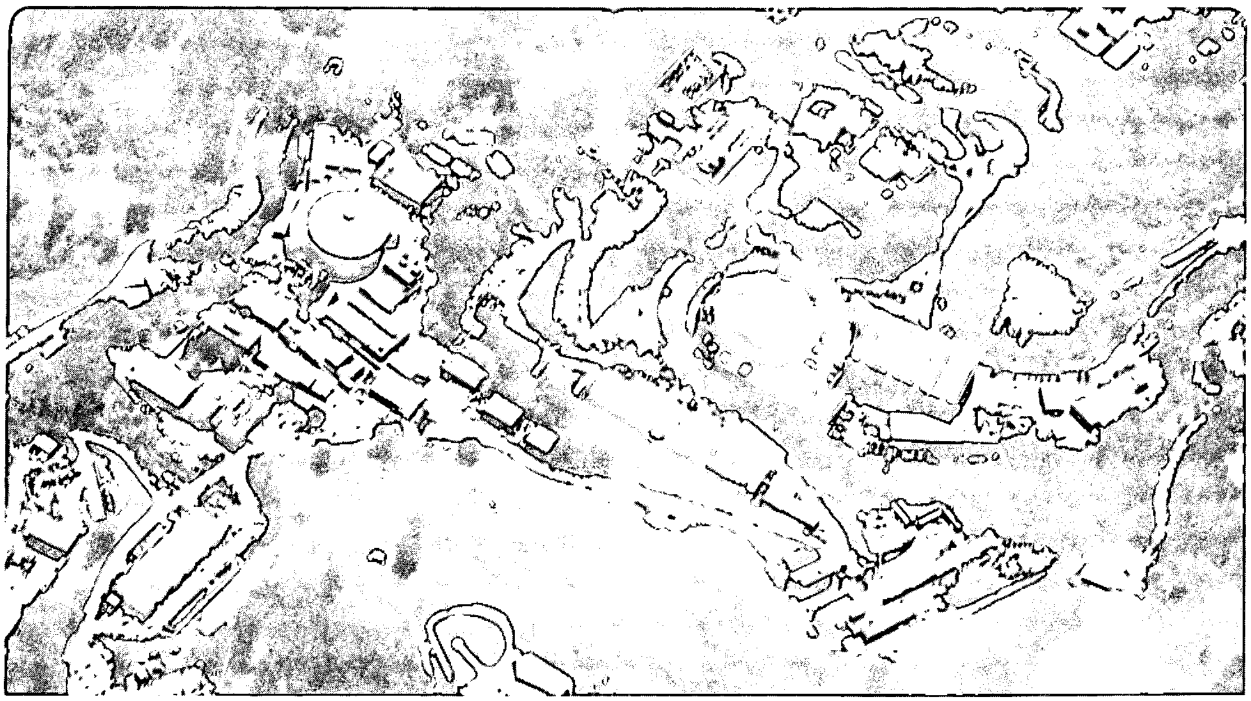

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Quantum Theory of Conciousness *

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Abstract

Heisenberg's conception of the physical universe is combined with William James' conception of mind to form a simple model of the mind/matter universe. This model realizes Sperry's idea of supervenient top-down control of brain processes by subjective conscious experience. The fundamental process of nature is a sequence of Heisenberg events, and every conscious event corresponds to a Heisenberg event that actualizes a large-scale metastable pattern of neuronal activity. This pattern is isomorphic, in a specific way, to the conscious event. The quantum state of the brain determines the propensity, i.e., the tendency to occur, for each of the alternative possible subjective conscious experiences that might occur in a given situation. Heisenberg's indeterminacy principle entails that the selection of the single experience that actually does occur is not fixed by any known law of nature. James emphasized the unity of the conscious event. This unity led him to doubt the finality of classical physics, which is essentially reductionistic. In the present model the unity of each conscious event is a consequence of the unity of the corresponding Heisenberg event.

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QUANTUM THEORY OF CONSCIOUSNESS

1. Introduction

Classical physics has no natural place for consciousness. According to the classical precepts, the sole ingredients of the physical universe are particles and local fields, and every physical system is completely described by specifying the dispositions in space and time of these two kinds of localizable parts. Furthermore, the dispositions of these parts at early times determine, through certain 'laws of motion', their dispositions at all times. The system is logically complete in the sense that it does not logically require, for its description of nature, any things beyond the dispositions of the particles and local fields.

The two cited features of classical physics, namely its local-reductionistic and deterministic aspects, do not entail that there can be no conglomerates that act cohesively as unified wholes. Nor do they entail that such conglomerates cannot control in large measure the motions of their own parts. But these two features of classical physics do entail that, to the extent that classical physics is valid, the motions of material things can be controlled only by things that are themselves deterministically controlled, and, moreover, dynamically equivalent to the forces of classical physics. In particular, because subjective conscious experience is not logically entailed by the concepts of classical physics, any control over brain activity exercised by a conscious experience is, to the extent that classical physics is valid, dynamically equivalent to the control exercised by the classical forces. This equivalence renders conscious experience superfluous, in the sense that the evolution of the physical universe would be exactly the same whether subjective conscious experience exists or not.

The condition "to the extent that classical physics is valid" is critical. It is not satisfied in nature. Classical physics is unable to explain the basic properties of materials, even in inorganic, nonliving, unconscious systems. Yet the operation of the brain depends critically upon the subtle properties of the tissues that make it up. Hence there is no scientific basis for supposing that classical physical theory could provide an adequate conceptual foundation for understanding the dynamics of the mind-brain system. On the other hand, there are ample philosophical reasons to reject the notion that classical physical theory is adequate for this task. Without going here into these reasons I merely cite the complete failure of the three-century-old effort to reconcile the properties of mind with the concepts of classical physics.

Scientists other than quantum physicists often fail to comprehend the enormity of the conceptual change wrought by quantum theory in our basic conception of the nature of matter. For example, it has been claimed, in connection with the mind-brain problem, that the switch to the quantum ideas is 'incremental'. That is hardly the case. The shift is from a local, reductionistic, deterministic conception of nature in which consciousness has no logical place, and can do nothing but passively watch a pre-programmed course of events, to a nonlocal, nonreductionistic, nondeterministic, conception of nature in which there is a perfectly natural place for consciousness, a place that allows each conscious event, conditioned, but not bound, by any known law of nature, to grasp a possible large-scale metastable patterns of neuronal activity in the brain, and convert its status from "possible" to "actual".

Two revisions in physics lead to the possibility of this profound change in the role of subjective conscious experience in mind-brain dynamics. The first is the opening up, by Heisenberg's indeterminacy principle, of at least the logical possibility that some entity not strictly controlled by the mechanical laws of physics *could* exercise supervenient downward control over the course of physical events. The second is the introduction into physics of physical events that are appropriate counterparts to conscious events, in the critical sense that each such physical event can actualize, as a whole, a complex large-scale metastable pattern of physical activity generated within a complex physical system by the action of the mechanical laws.

2. Heisenberg's Picture of the Physical World.

According to the strictly orthodox view, quantum theory provides no ordinary sort of picture of the physical world itself. Its principal founders, Bohr and Heisenberg, insisted that the theory must, strictly speaking, be viewed as merely a set of rules for making predictions about observations obtained under certain special kinds of experimental conditions.[1] The detailed form of these quantum predictions is such as to render quantum theory logically incompatible with any local–reductionistic physical world of the kind postulated in classical physics.[2] However, Heisenberg did eventually offer a highly nonclassical kind of picture of the physical world itself.[3] Heisenberg's picture may not be the only possible conception of nature compatible with the predictions of quantum theory [4], but it is certainly a possible one, and it is , I believe, the image currently favored by the majority of the practicing quantum physicists who allow themselves the luxury of a coherent conception of the physical world itself.

My proposal regarding consciousness is based on Heisenberg's picture of the world, or, more accurately, upon my elaboration upon his picture, which he did not describe in great detail. The central idea in Heisenberg's picture of nature is that atoms are not 'actual' things. The physical state of an atom, or of an assembly of atoms, represents only a set of 'objective tendencies' for certain peculiar kinds of 'actual events' to occur. These events are things of a new and entirely different kind. Moreover, the fundamental dynamical process of nature is no longer one single uniform process, as it is in classical physics. It consists rather of two different processes. One of these processes is a continuous, orderly, deterministic evolution. This process is controlled by fixed mathematical laws that are direct generalizations of the laws of classical physics. However, this process does not control the actual things themselves. It controls only the propensities, or objective tendencies, for the occurrence of the actual things. The other dynamical process consists of a sequence of unruly 'quantum jumps'. These jumps are not individually controlled by any known law of physics. Yet collectively they conform to strict statistical rules. These quantum jumps are considered to be the 'actual' things in nature. They are Heisenberg's actual events.

Heisenberg described his picture of the world in connection with the behavior of a quantum measuring device. In that context it is important to recognize that quantum theory naturally accommodates transformations of variables. Thus in the description of large objects one need not use directly the coordinates of the individual particles. It is often more useful to introduce variables that represent various 'observable' features of the object.

Our direct sensory perceptions of a macroscopic object containing a huge number of particles can be represented by a relatively small number of 'observable' variables. Each of these variables can be confined by the data obtained by our direct sensing of the object only within an interval that is generally so large that quantum effects become irrelevant. Of course, one might try to use some device to probe those features not describable in terms of these observable variables, but then our direct sensory impressions would be of the observable characteristics of that device. Thus we human beings are effectively imprisoned in the physical world described by observable variables: we can access the rest of the physical world only through this extremely limited set of variables. This fact is crucial to the application of quantum theory.

In the typical measurement situation discussed by Heisenberg there is a measuring device that is being used to measure some property of an atomic–sized quantum system. The device must be in a state of unstable equilibrium, so that a small signal from the atomic–sized system can trigger a chain of events leading to a change of certain observable features of the device.

In this situation there is the possibility of a change of the observable macroscopic state of the device from one metastable configuration to another. Here Heisenberg introduces his key idea, the notion of an 'actual event'. The possibility of introducing into physical theory this new concept of an actual event arises from the fact that the deterministic part of the quantum dynamics is expressed in terms of a quantity that, from a mathematical point of view, ought to represent probabilities. Yet within the mathematics itself there is no clear indication of exactly what these probabilities refer to – – what these probabilities are probabilities *of*.

Heisenberg supplied an answer by proposing, in effect, that certain probabilities defined by the theory be interpreted as the 'objective tendencies', or propensities, for corresponding *actual events* to occur. Each of these actual event is the actualization of one of the distinct metastable configurations of the observable degrees of freedom generated by the mechanical laws of motion , and the eradication of all those remaining patterns of physical activity that might have been actualized, but were not.

The introduction of these actual event carries quantum theory far beyond the ontologically neutral stance of the strictly orthodox interpretation. In the orthodox interpretation the quantum probabilities are interpreted as simply the probabilities that the community human observers will 'observe' particular ones of these distinct metastable states. The difference between this orthodox interpretation in terms of observations and Heisenberg's ontological interpretation in terms of actual events, is, at the practical level, completely negligible in all experimental situations that have yet been examined. Yet there is an important theoretical difference: Heisenberg's picture allows quantum theory to be viewed as a coherent description of the evolution of physical reality itself, rather than merely a set of stark statistical rules about connections between human observations.

3. Brain Dynamics

The human brain is a device that can process sensory inputs, formulate possible responses to the sensed situation, select a response, and oversee the execution of that response. This activity is dependent on the momentary physical state of the brain, which is a product of many factors, such as genetic structuring, conditioning, learning, and self–organization (e.g., reflection), among many others. The brain contains a huge network of neurons linked at synapses. These synaptic links allow electrical pulses in neurons to tend to produce or inhibit similar pulses in other neurons. The complex feed–back and feed–forward linkages allow the occurrence of an immense number of alternative possible metastable reverberating patterns of neural pulses. The persistence for a short time of such a pattern apparently [5] conditions the synaptic junctions in a way that facilitates the excitation of this pattern as a component of subsequent metastable patterns of reverberation.

In the formulation and execution of a bodily response a key role must be played by the *body schema*, which is the brains representation of the dispositions of the parts of the body that it is supervising. This body schema is associated with an *external world schema*, which is the brains representation of the environment of the body that is represented by the body schema. These two schema are essentially stable: they do not change spontaneously; they are changed only by a particular process, which replaces the "current" schema by a new one, and places the old one into an appropriate slot in an *historical schema.*

In addition to the body schema and the external world schema there is a *belief schema*, and these three representations are parts of the '*self and world*' *schema.* This latter schema lies at the 'current' end of a general historical schema, into which each 'self and world' schema is placed when it is displaced by a new one.

4. Consciousness

My proposal for identifying conscious events with certain specific kinds of brain events in Heisenberg's quantum mechanical picture of physical reality is based upon three observations:

1. The schema described above are 'classical' in the sense that they can be examined and manipulated in ways analogous to the ways that we examine and manipulate macroscopic objects: the schema are not appreciably disturbed by a mere examination, and they can be 'manipulated' by appropriate kinds of processing. It is therefore reasonable to suppose that these schema are represented by physical structures that are describable in terms of variables of the type that in measuring devices were called *observable*. In fact, these brain structures are the *only* structures that can ever really be 'observed': sensory inputs must be converted into the external–world schema (including affiliated buffers) before they can be perceived.

2. Brain processes involve chemical processes, and hence must, in principle, be treated quantum mechanically. In particular, the transmission process occurring at a synaptic junction is apparently triggered by the capture of a small number of calcium ions at an appropriate release site. In a quantum mechanical treatment, the locations of these calcium ions must be represented by a probability function. This effectively smears these particles over large regions, in a quantum statistical sense. Thus the question of whether or not a given synapse will transmit a signal is a problem that must be treated quantum mechanically: a quantum-mechanical component must be added to the other uncertainties, such as those generated by thermal noise, that enter into the decision as to whether or not the synapse will fire.

   There are hundreds of billions of synapses coupled together in a highly nonlinear fashion. And there must be a huge number of metastable reverberating patterns of pulses into which the brain might evolve.

Computer simulations [6] of brain networks in the classical case indicate that the final stable state into which a brain evolves is strongly dependent upon the synaptic parameters. Although analogous computations are needed for the quantum case it appears to me exceedingly probable, by virtue of, (1), the inherent sensitivity of nonlinear systems of this kind to variations in parameters, and, (2), the strong dependence of the process at the synaptic junction upon the locations of small numbers of calcium ions, and, (3) the large number of possible metastable states into which the brain might evolve, that, in the absence of any quantum jumps, a brain will generally evolve quantum mechanically from one metastable configuration into a *quantum superposition* of many metastable configurations, and sometimes into a superposition that ascribes nonnegligible quantum probabilities to several alternative possible metastable states of the 'self and world' schema. Note that the fatigue characteristics [5] of the synaptic junctions will cause any given metastable pattern to become, after a short time, unstable: the system will thus be forced to search for a new metastable configuration, and will therefore continue to evolve, if unchecked by a quantum jump, into a superposition states characterized by increasingly disparate self and world schemas.

3. The situation described above is, from the physical point of view, essentially the same as the one considered by Heisenberg, with the human brain in place of his measuring device. Thus if one accepts his picture of the world then one must accept also that if the brain evolves into a superposition of states characterized by different 'self and world' schema then an actual event must select and actualize one of these 'observable' states, and eradicate the others. I propose to identify each such actual brain event with a conscious event, and, conversely, to identify each conscious event with an actual brain event of this particular kind.

The only relativistically invariant way to represent a Heisenberg actual event is by a change in the Heisenberg state of the universe. In the interim between actual events there is, in the Heisenberg picture, only a global structure of potentialities that extends uniformly over all of spacetime. There is, in keeping with the special theory of relativity, no structure that connects a spacetime point to another point that is 'simultaneous with it' in any favored physical sense. However, each actual event is localized: each actual event is associated with a local spacetime region in which a certain classically describable metastable pattern of activity is actualized. This event is represented by a sudden jump in the global Heisenberg state of the universe.

Within the general framework of the Heisenberg picture an actual event *could* occur already at the level of the firing of an individual neuron: an actual event *could* fix whether a certain individual neuron does or does not fire.However, von Neumann's analysis of the process of measurement shows that the actual events in the brain *need not* occur at the level of the individual neurons: an actual event can perfectly well actualize *the entire large-scale integrated pattern of neural excitations associated with the metastable state of the brain that goes along with a particular conscious thought.* Indeed, von Neumann's words seem to suggest [7] that *all* actual events are events of this kind. However, in the Heisenberg ontology adopted here the actual events are not *exclusively* conscious events. On the other hand, every conscious event is an actual event: it is an event that *selects one of the alternative possible high-level meta-stable configurations of brain activity from among the host of such patterns mechanically generated by the Schroedinger equation.* Each conscious event corresponds, therefore, to an entity that *supervenes* over the quantum mechanical laws analogous the laws of classical physics: the conscious event corresponds to a Heisenberg event that actualizes the classically describable metastable quantum state of the brain that represents this conscious experience in the physicist's description of nature.

Remarks

1. The purpose of conscious thought is to guide the organism. This must be done by forming a projection into the future, and, more specifically, by forming a projected 'self and world' schema Thus, one step ahead of the current 'self and world' schema is the *projected* 'self and world' schema. This is the thing that is selected by a conscious act. It is the template that directs the subconscious processes that control, among other things, the motor activities.

2. The physical event is 'functionally equivalent' to the corresponding psychological event. The physical event selects a projected 'self and world'

schema that acts as the template for brain action , whereas the corresponding psychological event selects the associated imagined projected 'self and world'. Thus the identification of these events is neither ad hoc nor arbitrary: it is an expression of their functional equivalence.

3. To justify this claim of 'equivalence' an isomorphism must be established between the intrinsic structure of a conscious thought, as it is described by psychologists such as James, and the intrinsic structure of the 'projected self and world schema', which is the template that directs the unconscious processes of the brain in the way specified by that conscious thought. This key issue is addressed in reference [8].

4. The model shows how experiences exhibiting the empirically established features of conscious experience can arise essentially automatically out of quantum theory, provided the brain operates in the way suggested by Heisenberg's picture of nature. The theory is predictive in that it entails that brain process must be controlled by a top–level process having the specific dynamical and structural features, expressed in terms of self and world schema and memory, described in reference [8]

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